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## 1. “duhs”

the duhs are things that we just need to remember. these should be muscle memory, no questions asked, no math involved:

$f$	$\frac{df}{dx}$	long form
$\sin(x)$	$\cos(x)$	$\int \cos(x)dx = \sin(x) + C$
$\cos(x)$	$-\sin(x)$	$\int \sin(x)dx = -\cos(x) + C$
$x$	$1$	$\int dx = x + C$
$e^x$	$e^x$	$\int e^x dx = e^x + C$
$\tan(x)$	$\sec^2(x)$	$\int \sec^2(x)dx = \tan(x) + C$
$\ln(x)$	$\frac{1}{x}$	$\int \frac{1}{x}dx = \ln x  + C$
$\arctan(x)$	$\frac{1}{1+x^2}$	$\int \frac{1}{1+x^2}dx = \arctan(x) + C$

it isn't quite a duh but the fundamentally important rule for quick integration is the power rule:

$$\frac{d}{dx}x^n = nx^{n-1}$$

$$\implies \frac{d}{dx} \frac{x^{n+1}}{n+1} = x^n$$

so from this we can discern:

$$\int x^n dx := \begin{cases} \frac{x^{n+1}}{n+1} + C & \text{if } n \neq -1 \\ \ln|x| + C & \text{if } n = -1 \end{cases}$$

## 2. u-substitution

how do we solve this?

$$\int x(x^2 + 1)^{50} dx$$

u-sub is “the chain rule in reverse”

u-sub has 6 steps (in the context of the given problem):

1.  $u = x^2 + 1$  : identify the u (this is our u-sub we work with)
2.  $\frac{du}{dx} = 2x$  : now we find the u’
3.  $du = 2x dx$  : now we find the du alone
4.  $\frac{1}{2} \int u^{50} du$  : putting it back into context
5.  $\frac{1}{2} \frac{u^{51}}{51} + C$  : “solved”
6.  $\frac{1}{2} \frac{(x^2+1)^{51}}{51} + C$  : back-substitution

done.

an example:

$$\int e^{10x} dx$$

$$u = 10x \implies \frac{du}{dx} = 10 \implies du = 10dx$$

### 3. integration by parts

this is in stewart calc ch7.1

$$\int (uv)' = \int u'v + \int uv'$$

$$uv = \int vdu + \int u dv$$

$$\int u dv = uv - \int v du$$

memorize:

$$\int u dv = uv - \int v du$$

worked example:

$$\int x \ln x dx$$

$$u = \ln x \text{ and } dv = x dx$$

$$du = \frac{1}{x} dx \text{ and } v = \frac{x^2}{2}$$

as per the formula:

$$\begin{aligned} \int u dv &= uv - \int v du \\ \int x \ln x dx &= \frac{x^2}{2} \ln x - \int \frac{x^2}{2} \cdot \frac{1}{x} dx \\ &= \frac{x^2}{2} \ln x - \int \frac{1}{2} x dx \\ &= \frac{x^2}{2} \ln x - \frac{x^2}{4} + C \end{aligned}$$

#### 3.1. integrating $\ln(x)$

$$\int \ln x dx$$

$$u = \ln x \text{ and } v = x$$

$$du = \frac{1}{x} dx \text{ and } dv = dx$$

$$\begin{aligned} \int \ln x dx &= \ln(x)x - \int x \cdot \frac{1}{x} dx \\ &= x \ln x - x + C \end{aligned}$$

## 4. partial fractions

$$\frac{21}{35} = \frac{A}{5} + \frac{B}{7} = \frac{7A + 5B}{35}$$

$$7A + 5B = 21$$

this is an underdetermined system of equations, because the answers to what A and B are are not uniquely determined

Ex:

$$\int \frac{2}{x^2 - 2x} dx$$

$$\frac{2}{x^2 - 2x} = \frac{2}{x(x-2)} = \frac{A}{x} + \frac{B}{x-2}$$

$$\frac{2}{\cancel{x(x-2)}} = \frac{A(\cancel{x-2}) + Bx}{\cancel{x(x-2)}}$$

and now you have a simple system to solve

$$Ax - 2A + Bx = Ux + Z$$

$$A + B = 0$$

$$-2A = 2$$

$$\Rightarrow A = -1, B = 1$$

(this may also be done with reduced row echelon form as long as a proper identity matrix can be formed on the left side of the matrix. if your name is noah "alex" yurasko, you can probably do this method)

returning to the integral:

$$= \int \left( -\frac{1}{x} + \frac{1}{x-2} \right) dx$$

$$= -\ln|x| + \ln|x-2| + C$$

there are some cases where this is useful:

1. denominator has distinct linear factors (factors do not result in a power)

(he only wrote one case)

**4.1. worked example with 3 terms**

$$\int \frac{x^2 + 2x + 1}{2x^3 + 2x - 2} dx$$

(going to put this example in later, i have it in notebook)

**4.2. worked second example**

$$\int \frac{x^2 + 1}{(x-1)(x-2)(x-3)} dx$$

$$\frac{A}{x-1} + \frac{B}{x-2} + \frac{C}{x-3} = A(x-2)(x-3) + B(x-1)(x-3) + C(x-1)(x-2)$$

(noah has this to be inserted TODO)

**4.3. repeated roots**

$$\int \frac{6x + 7}{(x+2)^2}$$

$$\frac{6x + 7}{(x+2)^2} =$$

## 5. appendix

### 5.1. rules from 05/02

$$\frac{d}{dx} \tan(x) = \sec^2(x)$$

$$\frac{d}{dx} \cot(x) = -\csc^2(x)$$

$$\frac{d}{dx} \sec(x) = \sec(x) \tan(x)$$

$$\frac{d}{dx} \csc(x) = \csc(x) \cot(x)$$

### 5.2. identities from 05/02

$$\sin^2(x) = \frac{1 - \cos(2x)}{2}$$

$$\ln(a^r) = r \ln(a)$$

$$\sin^2(x) + \cos^2(x) = 1$$

$$\cos^2(x) = \frac{1 + \cos(2x)}{2}$$

$$\tan^2(x) + 1 = \sec^2(x)$$

### 5.3. integrals from 05/02

$$\begin{aligned} \int \tan^2(x) \\ &= \int \sec^2(x) - 1 dx \\ &= \tan(x) - x + C \end{aligned}$$

### 5.4. table of trigonometric substitutions

expression	substitution	identity
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